THE BONDI ANTICLINE.

By C. Hedley, F.L.S.

(Plates xxv.-xxvii.)

To ascertain the quality and position of coal-seams beneath and inland from Sydney, a series of bores were drilled to a great depth. As a result, the conformation of the remotely underlying strata is unusually well known in this neighbourhood.

Sections* composed from these borings develop a central basin rising to the coast on the one side, and to the Blue Mountains on the other. This basin is here regarded as the lap of a fold. Had the basin existed before the deposition of the strata it contains, then salt would have accumulated in an area of internal drainage below sea-level. Further, the steep slope, on the western side, of about five thousand feet in forty miles would have thrown brisk streams, and would not have supported such swamps as grew the coal. Consequently, the bowed strata were not laid down in their present attitude, but on an almost level surface. So considerable deformation of the original coal-horizon has therefore happened. Since drawing the following sketch, it occurs to me that the watershed, on which was laid down the Hawkesbury Sandstone, might have descended inland westwards, while the granite mountain-range, whose waste supplied its materials, was situated seawards and to the east. This would harmonise with deeper, coarser deposits on the east becoming finer and thinner on the west.

Compressive crustal action has already been suggested (*ante*, xxxvi., p.14) as an agent competent to effect the changes that have taken place. On this hypothesis, both the coal and the succeeding shale and sandstone were spread evenly on an almost level floor, and by subsequent earth-movements were compressed and bent, first into smaller, then into larger, folds—wavelets on a wave (text-fig. 1).

* Carne, Mem. Geol. Survey N.S.W., Geol. vi., 1908, p.160.

Various alternations of Wianamatta shale and Hawkesbury sandstone indicate the former, while the latter are represented

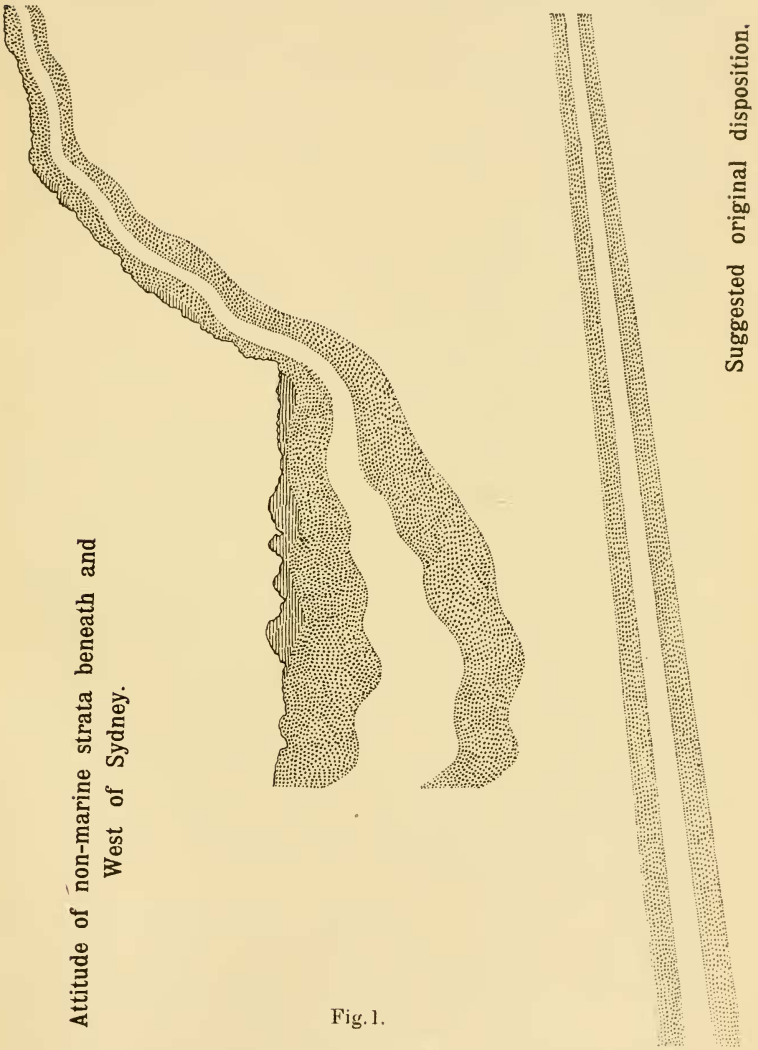

Fig. 1.

by the anticlinal ridge of the Blue Mountains and by the synclinal trough from Blacktown to Campbelltown. The strata

rising with increased rapidity near Sydney* point to the completion of the series by an anticline on the east. It is proposed to name this the Bondi Anticline. Apparently its crest lay beyond the present coast, and though now shattered and sunk, may yet be traced from its dyke-complex, and from the crushing of the rocks before it.

In its prime, the Bondi anticline probably rose to a considerable height, for denudation has pared off from its flanks the Wianamatta shale and some sandstone as well. The drowned valley of Port Jackson indicates recent subsidence; so that the anticline sank, perhaps through the withdrawal of a fluid core, perhaps through being involved in another and larger folding movement, or perhaps through faulting.

Evidence in support of this idea is offered from the radiating dykes and from the crushing of the shale.

(1) *The radial dykes.*—Around Sydney, the sandstone-rocks are fissured by a series of dykes, some of which run roughly north and south, and others cross at about right angles. Both are of later date than the crushing of the shale, as they traverse the distorted strata indifferently.

It was remarked by Mr. G. A. Waterhouse that the easterly and westerly series assumed a radial direction, and converged to a point east of Bondi.†

If the Bondi anticline swelled to bursting point and then cracked lengthwise and crosswise, these dykes would be the casts of those cracks (Plate xxv.). By their direction, the hypothetical anticline might be restored as a crescent billow convex to the present coast and rising in the centre. When pressure was relieved by the bursting of the lava into dykes, the folding movement was perhaps arrested.

(2) *The mashing of the anticline.*—In the composition of the Hawkesbury Sandstone, the Rev. J. E. Tenison-Woods distinguished a smaller stratification, whose lines are mostly inclined to the horizon, as "laminæ," and a greater division,

* David & Pittman, Journ. Roy. Soc. N. S. Wales, xxvii., 1893(1894), p. 459.
† Morrison, Rec. Geol. Survey N.S.W., vii., 1904, p. 261.

including one or more series of laminæ, as "layers." Between these layers, there is often a bed of shale. This shale may be yards in thickness, reduced to a thin sheet or spattered about in discs and pebbles.

Near Sydney, the lip of the basin bearing the brunt of the pressure, the shale is rarely undisturbed. Frequently, it rests on a floor which curves abruptly up and down, and underlies a roof which, in a short space, makes equally sudden contortions (Plate xxvi.). From its nature, the shale, deposited horizontally in calmest pools, could not have formed on such a floor or under such a roof. Into present positions the shale has slid over a strange floor, and been wedged under a misfit roof. Sometimes a shale bed thinning out is continued by a stream of biscuit-shaped flakes. These are morsels chewed in the jaws of the sandstone layers. Fish-remains are abundant in some shale-beds, and such are usually distorted by a very slow oblique pressure they have undergone. The sudden bumping of stranded icebergs could not account for the screwing these fossils have received. Besides, under floating ice the shale would disintegrate rather than bend or break. Pressure, too, is perhaps expressed by the readiness of exposed shale to crumble away, due to the breaking of its grain.

The butter would ooze out, if pressure were put upon a pile of slices of bread and butter. So where hard sandstone and soft shale were squeezed together, the shale first gave way, and thus furnishes the most obvious evidence of displacement. To some extent, the false bedding disguised dislocation, but, though less apparent, the sandstone exhibits its own signs of disturbance. Continually it falls in belly-sags, and rises in back-humps, the imprint of thrust-movements. Layers are rolled over or telescoped into each other, and in places the sandstone is curled like carpenter's shavings (Plate xxvii.).

Such phenomena are well known. Mr. C. S. Wilkinson* described disturbed beds at Fort Macquarie, Woolloomooloo, and Flagstaff Hill, where there were "angular boulders of the shale

* Wilkinson, Journ. Roy. Soc. N.S.W., xiii., 1879(1880), p.106.

of all sizes up to twenty feet in diameter, embedded in the sandstone in the most confused manner": also rounded pebbles of shale "usually oval in shape and embedded in such a manner that the longer axis of the pebble is nearly always inclined, or dips towards the South-west." In his matured opinion, these rocks were broken and pushed by the movement of ice.*

Contorted beds at Coogee were figured and described by Prof. David,† who accepted Mr. Wilkinson's explanation that the disturbance was caused by the grounding of contemporary icebergs.

Objections to this theory were raised by the Rev. J. E. Tenison-Woods,‡ who contended that the usual accompaniments of ice-action, such as transported and engraved stones, moraines, till, glacial mud, or boulder clay, are here absent. He considered that the breaking and scattering of the shale might have been accomplished by the floods of contemporary streams.

Mr. R. D. Oldham‖ was not convinced that the evidence advanced by Mr. Wilkinson proved the presence of glaciers.

Neither afloat nor aground does ice work thus. Transported rocks, so constant a feature of ice, and so easy to detect, are absent here. It is now submitted that neither ice-action nor contemporaneous denudation satisfactorily explains the crushed shales. On the contrary, it is thought that their injuries were received when they were caught in the press of the Bondi anticline, and ground between moving masses of sandstone, and that the disturbances arose from a series of thrusts and folds started in the yielding and quaking mass by the advancing anticline.

From an economic point of view, it will be of importance to consider if the coal-deposits in this area have deteriorated by crushing.

The dune-and-pond origin of the Hawkesbury Sandstone, so ably advocated by Tenison-Woods, would be favoured by the withdrawal of the ice-hypothesis.

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* Wilkinson, Mem. Dept. Mines, Pal. iii., 1890, p.28, footnote.

† David, Quart. Journ. Geol. Soc., xliii., 1887, pp.190-196.

‡ Ten.-Woods, Proc. Roy. Soc. N. S. Wales, xvi., 1882(1883), p.75.

‖ Oldham, Rec. Geol. Survey India, xix., 1886, p.43.

In conclusion, the Bondi anticline is suggested as the medium of that tremendous driving force which thrust down the basin now outlined by the Wianamatta shale, till the Prospect lava squirted through its broken floor, displaced the Hawkesbury River from Camden to Windsor, and pressed up the Blue Mountain ridge behind. The giant fold, of which it was a part, relaxed its grip and died in its youth, as the anticline cracked and burst.

EXPLANATION OF PLATES XXV.-XXVII.

Plate xxv.

Scheme of an anticline deduced to match the Blue Mountain ridge and the Parramatta trough, and to account for the disturbed shales and sandstones about Sydney. From the paths of the radial dykes it is developed as a crescent directed west and swollen medially near Bondi. Based on the Geological Sketch Map of Sydney, Dept. Mines, 1903.

Plate xxvi.

Example of a crumpled sheet of shale regarded as entangled in a slide of the sandstone-beds. Opposite Cremorne Wharf, Milson Road in the foreground. Drawn by Miss P. Clarke.

Plate xxvii.

A series of coils of sandstone which, it is presumed, were slowly rolled up and together when a superincumbent mass of rock was launched across them. From the road side, between Seaforth and the Spit, east side of Middle Harbour. Photographed by Dr. H. G. Chapman.